CYANIDE GAS FOR THE DESTRUCTION OF INSECTS.

WITH SPECIAL REFERENCE TO MOSQUITOES, FLEAS, BODY LICE, AND BEDBUGS.

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Effectiveness is the most important element to be considered in the selection of a fumigant.

This factor being assured, the relative cheapness of the materials used, the duration of exposure necessary for destruction, the toxicity of the fumigant to human life, and the effect of the gas upon fabrics, furnishings, or merchandise, are all factors that should be given weighty consideration.

The United States Quarantine Regulations include sulphur dioxide, pyrethrum, and cyanide gas as agents for the destruction of mosquitoes and other vermin, the sulphur dioxide to be used in the proportion of 2 pounds of sulphur to each thousand cubic feet of space, the exposure to be for two hours; the cyanide gas to be used in the proportion of 10 ounces of potassium cyanide to each thousand cubic feet of space, the time of exposure not specified; and pyrethrum in the proportion of 4 pounds to each thousand cubic feet of space for two hours' exposure.

In 1910 Mitzmain [1] performed a series of experiments to demonstrate the effect of cyanide gas, sulphur dioxide, and several other agents on fleas, both in the adult and larval stage. His results from cyanide gas were somewhat inconstant, and the writers are inclined to agree with him that he may have been working with a deteriorated chemical.

In 1910 Stevenson,[2] of Bombay, also reported experimental results on "the killing of rats and rat fleas by hydrocyanic acid gas." This series of experiments was carried out under artificial conditions that simulated the natural.

In 1911 McClintock and Hamilton [3] reported a very thorough and comprehensive study of the effect of various insecticides (including cyanide gas and sulphur dioxide) upon mosquitoes, bedbugs, flies, and cockroaches. Their experimental environment was purely artifical, and no attempt was made to simulate the natural conditions under which the destruction of such insects would ordinarily be practiced.

Stevenson found that fleas were killed by cyanide gas in the strength of 3 ounces potassium cyanide (KCN) per 1,000 cubic feet

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[1] Maurice B. Mitzmain: Notes on agents used for flea destruction—Public Health Reports, July 29, 1910.

[2] Capt. W. D. H. Stevenson, I. M. S. Preliminary report on the killing of rat fleas by hydrocyanic acid gas. Scientific memoirs by officers of the medical and sanitary departments of Government of India, No. 38 N. S., 1910.

[3] Chas. McClintock, H. C. Hamilton, and F. B. Lowe: A further contribution to our knowledge of insecticides—fumigants. Journal of the American Public Health Association, April, 1911.

of space, exposure for 40 minutes when ordinary protection was afforded.

McClintock and Hamilton found that mosquitoes without protection in a bell jar were destroyed by cyanide gas in the strength of 2 grams potassium (KCN) per 800,000 cubic centimeters (approximately 2½ ounces per 1,000 cubic feet), and bedbugs under the same condition by the gas in the strength of 6.3 grams per 800,000 cubic centimeters (approximately 8 ounces per 1,000 cubic feet).

The fumes of pyrethrum merely stupify mosquitoes, and it has been more or less discarded as a fumigant.

The writers have conducted a series of practical experiments during the past year in order to determine the comparative insecticidal values of cyanide gas and sulphur dioxide.

Potassium cyanide c. p. (or the equivalent of sodium cyanide), sulphuric acid 66B, and water were combined in the proportion by weight of 1 part cyanide, 2 parts acid, and 2½ parts water.

The technique in the preparation of cyanide gas was the same as that described in reprint 313, from the Public Health Reports, December 3, 1915.

For the various purposes of the experiments the tests were performed in a room of 1,269 cubic feet capacity, with all openings sealed while the fumigation was in progress. Bedbugs, body lice, roaches, and several species of mosquitoes and fleas were used in the experiments.

The insect containers were placed on the floor of the room, except in series "L." and "M.," when a comparison was made of the strength of gas in the upper and lower air levels.

A small glass of 6-ounce capacity, a larger jar of 1-gallon capacity, and an iron can of 16½-gallon capacity were the containers used.

The insects within the containers were afforded varying degrees of protection by layers of muslin firmly bound over the top of receptacle, ranging from one to six layers.

The cloth which is referred to in the text as "muslin" or "cheesecloth" is a product commercially designated as bunting of class "A" grade. It is probably somewhat heavier and more closely woven than the best grade of gauze used in surgical practice.

In some of the experiments the smaller container holding the insects was placed within the large can (covered) thus affording a double protection that would seldom be found in actuality.

In some of the containers the insects were also given the additional protection of loosely packed cheesecloth.

During the series the outdoor temperature varied from 33° to 70° F. but with no noticeable difference in results.

It may be, as suggested by Roberts, that very low temperatures affect the potency of the fumigation. We are not able to pass any

opinion on this possibility, as at no time was the weather below freezing.

The first inspection of results was made immediately after opening the fumigating room, the final observation being made 24 hours thereafter, except in such cases as are otherwise notated in the tabulations.

The results are presented in tabular form according to the agent used, the insect exposed and the environmental condition.

For statistical convenience the results are tabulated as separate experiments, but, in general, in the same series several containers having different degrees of protection were exposed at one time.

General Consideration.

It is comparatively easy to determine a standard amount of any fumigant necessary to kill unprotected insects. The difficulty lies in estimating the degree of protection ordinarily secured by these insects under natural conditions.

The standards arrived at by us are therefore provisional, applying to generally existing conditions and not to extraordinary or unusual situations. While we believe that cyanide gas in the proportion of $2\frac{1}{2}$ ounces of potassium cyanide per 1,000 cubic feet of space, exposure for one hour, will destroy fleas in the majority of instances, we realize that such a strength of the gas would hardly kill these insects were they lodged in tightly packed baggage.

It is assumed, however, that the supervisor of the fumigation would remove unusual harboring facilities, more especially in treating infected places; that clothes closets would be opened, baggage unpacked, bedclothes and mattresses rearranged, and wearing apparel spread out; all to the end of promoting penetration of the fumigating gas.

With the above reservation, therefore, we believe that our standards for strength of gas lethal to insects are dependable and give a fair margin of safety in considering the ordinary protection obtained by the various insects in their natural habitat.

From our series of tests and from observation of results in routine fumigation we advocate the following proportion, respectively, of cyanide or sulphur for insect destruction:

For mosquitoes.—Potassium cyanide, 0.4 ounce per 1,000 cubic feet of space, exposure for 15 minutes.

Sulphur, 2 pounds per 1,000 cubic feet of space, exposure for 1 hour.

For bedbugs.—Potassium cyanide, 5 ounces per 1,000 cubic feet of space, exposure for 1 hour.

For body lice.—Potassium cyanide, 10 ounces per 1,000 cubic feet of space, exposure for 2 hours.

Sulphur, 4 pounds per 1,000 cubic feet of space, exposure for 6 hours.

For roaches.—Potassium cyanide, 10 ounces per 1,000 cubic feet of space, exposure for 1 hour.

Sulphur, 4 pounds per 1,000 cubic feet of space, exposure for 6 hours.

For fleas.—Potassium cyanide, $2\frac{1}{2}$ ounces per 1,000 cubic feet of space, exposure for 15 minutes.

As it is of questionable propriety to contemplate flea destruction without the coordinate killing of rats (when employed as a sanitary measure), we made no comparative studies of sulphur as an insecticide for fleas, but refer to the article on cyanide gas in Public Health Reports of December 3, 1915, wherein we recommended a standard of 5 ounces of cyanide or 4 pounds of sulphur per 1,000 cubic feet for the destruction of rats and fleas.

The unit price of cyanide fumigation in the proportion of 5 ounces cyanide per 1,000 cubic feet of space is 9 cents at the present price of chemicals (25 cents per pound for potassium cyanide and $3\frac{1}{2}$ cents per pound for sulphuric acid).

The price of sulphur fumigation per 1,000 cubic feet is 10 cents in the strength of 4 pounds of sulphur per 1,000 cubic feet.

The comparative cost of sulphur and cyanide fumigation per 1,000 cubic feet based on the provisional standard advocated above would be:

Fumigation for—	Cost of cyanide gas per 1,000 cubic feet.	Cost of sulphur dioxide per 1,000 cubic feet.
	Cents.	*Cents.*
Destruction of mosquitoes	0.7	5
Destruction of body lice	18	10
Destruction of bedbugs	9	5
Destruction of roaches	18	10
Destruction of rats and fleas	9	10

From this it can be seen that cyanide gas is much cheaper than sulphur dioxide for mosquito destruction, costing only one-seventh as much as the latter gas, aside from requiring a much less duration of exposure.

In the proportion of 0.4 ounce cyanide per 1,000 cubic feet of space the dilution of the gas after diffusion is approximately 1 part cyanogen to 6,000 parts of air, so dilute, in fact, as to practically eliminate all possible danger to human life. On repeated occasions we entered the fumigating room immediately upon opening the door after mosquito fumigation without noticing any ill effect.

For destroying bedbugs, roaches, and body lice sulphur is a cheaper fumigant than cyanide, but the latter possesses obvious advantages in lessened duration of exposure and noninjurious effect on fabrics, furnishings, merchandise, etc.

However, the comparative benefits between sulphur dioxide and cyanide gas as fumigants were set forth in Public Health Report of December 3, 1915, and need not here be rehearsed.

TABLE I.—*Series "A"—Effects of cyanide gas (HCN) on mosquitoes.*

No. of experiment.	Number of mosquitoes.	Container.	Cheesecloth protection to container.	Strength of gas.	Time of exposure.	Primary inspection.	Final inspection 24 hours later.
1	4	Glass jar, capacity of 6 ounces.	1 layer	5 ounces potassium cyanide (KCN) per 1,000 cubic feet of air space.	One-half hour	All insects stupefied.	All insects dead.
2	4	do	2 layers	do	do	do	Do.
3	4	do	3 layers	do	do	do	Do.
4	4	do	4 layers	do	do	do	Do.
5	4	do	5 layers	do	do	do	Do.
6	4	do	6 layers	do	do	do	Do.
7	4	do	1 layer	0.8 ounce potassium cyanide per 1,000 cubic feet of air space.	10 minutes	do	Do.
a8	6	Glass jar, capacity of 6 ounces, within iron can of 16.5-gallon capacity.	6 layers over glass, 2 layers over can.	do	15 minutes	do	3 insects revived; 3 insects dead.
a9	4	do	1 layer over glass, 3 layers over can.	0.4 ounce potassium cyanide per 1,000 cubic feet of air space.	do	do	3 insects revived; 1 insect dead.
10	4	Glass jar, capacity of 6 ounces.	1 layer	do	10 minutes	do	All insects dead.
11	4	do	6 layers	do	do	do	Do.
12	4	do	1 layer	do	12 minutes	do	Do.
13	4	do	3 layers	do	do	do	Do.
14	4	do	6 layers	do	do	do	Do.
15	4	do	10 layers	do	do	do	Do.
16	4	do	5 layers	do	do	do	Do.
17	4	do	1 layer	do	15 minutes	do	Do.
18	4	do	6 layers	do	do	do	Do.
19	5	do	1 layer	do	do	do	Do.
20	6	do	6 layers	do	do	do	Do.
21	10	Iron can, capacity of 16.5 gallons.	3 layers	do	do	do	Do.
a22	4	Glass jar, capacity of 6 ounces, within iron can of 16.5-gallon capacity.	1 layer over glass, 2 layers over can.	0.9 ounce potassium cyanide per 1,000 cubic feet of air space.	do	do	Do.

REMARKS.—The species of mosquitoes used were: *Anopheles crucians*, *A. quadrimaculatus*, *Aëdes calopus*, *Culex tæniorhynchus*, and *C. quinquefasciatus*. Both male and female were exposed. Some of them were engorged, others had never fed. As between the various species, males and females, engorged and unengorged individuals, there might have been varying degrees of susceptibility to the effects of the gas, but such a possible variation can be of only academic interest. Cyanide gas in the strength of 0.4 ounce potassium cyanide per 1,000 cubic feet of space never failed to kill all the exposed mosquitoes, where the artificial conditions simulated the natural.

In experiments a8, a9, and a22, the mosquitoes were given a double protection that would hardly ever obtain under ordinary natural circumstances. From experiment a22 it seems probable that 0.9 ounce potassium cyanide per 1,000 cubic feet of space will kill mosquitoes under most extraordinary conditions, but as such conditions presumably rarely occur, it is believed that 0.4 ounce potassium cyanide per 1,000 cubic feet of space is a dependable strength of cyanide gas for the routine destruction of mosquitoes on vessels or in buildings.

TABLE II.—*Series "B"—Effects of cyanide gas (HCN) on fleas.*

No. of experiment.	Number of fleas.	Container.	Cheesecloth protection to container.	Strength of gas.	Duration of exposure.	Primary inspection.	Final inspection.
1	9	Glass jar, capacity of 1 gallon.	2 layers	0.4 ounce potassium cyanide (KCN) per 1,000 cubic feet of air space.	15 minutes	All insects stupefied.	All insects revived in 12 hours.
2	9	do	6 layers	do	do	do	Do.
3	9	do	2 layers	1.5 ounces potassium cyanide (KCN) per 1,000 cubic feet of air space.	do	do	All insects dead 24 hours later.
4	9	do	6 layers	do	do	do	Do.
5	7	do	1 layer	do	do	do	6 insects dead; 1 insect revived (end of 12 hours).
6	10	do	do	2.5 ounces potassium cyanide (KCN) per 1,000 cubic feet of air space.	do	do	All insects dead (end of 18 hours).

REMARKS.—The species of fleas used were *L. Cheopis*, *C. fasciatus*, and *Ct. musculi*, and for the most part the fleas were engorged and showed marked vitality before exposure to the gas. Fleas are more resistant to the effect of cyanide than are mosquitoes, but 2.5 ounces potassium cyanide per 1,000 cubic feet of space seems quite sufficient to kill fleas under the ordinary natural conditions. Were it not for the one surviving individual in experiment No. 7, 1.5 ounces of cyanide per 1,000 cubic feet of space would have been determined as a sufficient amount of cyanide for flea destruction.

TABLE III.—*Series "C"—Effects of sulphur dioxide (SO_2) on mosquitoes.*

No. of experiment.	Number of mosquitoes.	Container.	Cheese cloth protection to container.	Strength of gas.	Duration of exposure.	Primary inspection.	Final inspection 24 hours later.
				Per cent.			
1	6	Glass jar; capacity, 6 ounces.	6 layers	1	1 hour	1 insect alive, 5 dead, apparently	1 insect alive, 5 dead.
2	6	Glass jar; capacity, 6 ounces, within iron can of 16½ gallons capacity.	1 layer over glass jar, 2 layers over can.	1	do	4 insects alive, 2 dead	4 insects alive, 2 dead.
3a	4	Glass jar; capacity, 6 ounces.	1 layer	1	2 hours	All insects dead	All insects dead.
[1] 3b	4	do	3 layers	1	do	do	Do.
4a	4	do	do	1	do	3 insects dead, 1 alive	3 insects dead, 1 alive.
[1] 4b	4	do	do	1	do	All insects dead	All insects dead.
5a	5	do	6 layers	1	do	2 insects dead, 3 alive	2 insects dead, 3 alive.
5b	5	do	do	1	do	All insects dead apparently	All insects alive.
6a	4	do	10 layers	1	do	do	Do.
6b	4	do	do	1	do	do	Do.
7a	5	Glass jar, 6-ounce capacity, within iron can.	1 layer over jar, 3 layers over can.	1	do	2 insects dead, 3 alive	2 insects dead, 3 alive.
7b	5	do	do	1	do	All insects stupefied	All insects dead.
8a	3	Glass jar, 6-ounce capacity	1 layer	1	do	do	Do.
8b	3	do	do	1	do	do	Do.
9a	3	do	6 layers	1	do	do	Do.
9b	3	do	do	1	do	do	Do.
10	6	do	1 layer	1	1 hour	do	Do.
11	6	Glass jar, 6 ounces within can of 16½ gallons capacity.	1 layer over jar, 2 layers over can.	1	do	do	Do.
12	5	Glass jar, 6-ounce capacity	1 layer	2	2 hours	do	Do.
13	5	do	do	2	do	do	Do.
14	5	do	do	2	do	do	Do.
15	5	do	do	2	do	do	Do.
16	5	do	do	2	do	do	Do.
17	5	do	do	2	do	do	Do.

[1] REMARKS.—The results of sulphur fumigation of mosquitoes were irregular. This is attributed to the fact that in experiments 1, 2, and 3a to 7a, the sulphur had not entirely burned. The experiments in which the sulphur was consumed in the proportion of 1 pound per 1,000 cubic feet never failed to kill mosquitoes, whether the exposure was for 1 hour or 2 hours. As it is not an uncommon occurrence in the pot and pan method of fumigation that part of the sulphur is unconsumed, the writers believe this contingency should always be considered and an excess of sulphur (2 per cent, or 2 pounds per 1,000 cubic feet of space) be used for mosquito fumigation. One hour's exposure seems sufficient.

TABLE IV.—*Series "D"—Effects of cyanide gas (HCN) on bedbugs (artificial conditions).*

No. of experiment.	Number of insects.	Container.	Cheesecloth protection to container.	Strength of gas.	Duration of exposure.	Primary inspection.	Final inspection 24 hours later.
1	7	Glass jar, capacity of 6 ounces.	One layer	0.4 ounce potassium cyanide per 1,000 cubic feet air space.	20 minutes	All insects apparently dead.	All insects revived.
2	7	do	do	do	1 hour	do	Do.
3	7	do	do	0.9 ounce potassium cyanide per 1,000 cubic feet air space.	15 minutes	do	Do.
4	7	do	do	1.6 ounces potassium cyanide per 1,000 cubic feet air space.	do	do	5 insects revived; 2 insects dead.
5	12	do	Container loosely packed with cheesecloth and covered by one layer.	2.5 ounces potassium cyanide per 1,000 cubic feet of air space.	One-half hour	do	All insects revived.
6	12	do	do	5 ounces potassium cyanide per 1,000 cubic feet of air space.	do	do	10 insects dead; 2 insects alive.
7	12	do	do	do	1 hour	do	9 insects dead; 3 insects alive.
8	5	do	One layer	do	do	do	All insects dead.
[1] 9	6	do	Six layers	10 ounces potassium cyanide per 1,000 cubic feet of air space.	do	do	5 insects dead; 1 alive.
[1] 10	6	do	Six layers over jar; container loosely packed with gauze.	do	do	do	4 insects dead; 2 alive.
11	6	do	Six layers	5 ounces potassium cyanide per 1,000 cubic feet of air space.	do	do	All insects dead.
12	6	do	Six layers over jar; container loosely packed with gauze.	do	do	do	Do.
13	6	do	Six layers	do	do	do	Do.
14	6	do	Six layers over jar; container loosely packed with gauze.	do	do	do	Do.
[1] 15	5	do	One layer	3¾ ounces sodium cyanide per 1,000 cubic feet of air space.	do	All insects stupefied.	Do.
16	5	do	Six layers	do	do	do	Do.
17	5	do	Container packed with cheesecloth and covered by one layer.	do	do	do	Do.

[1] REMARKS.—Upon the failure of 10 ounces potassium cyanide to kill all insects (experiments 9 and 10), an investigation revealed the fact that the cyanide used in experiments 6, 7, 8, 9, and 10 had been taken from the powdered residue of a can of cyanide which had been exposed to the air for several days. A repetition of these experiments, i. e., 11 to 14, using cyanide that we were assured had not deteriorated, invariably resulted in the death of all insects. It seems evident that cyanide, if pulverized, will gradually deteriorate with exposure to air, so that in cyanide fumigation the lump form should be used, pulverizing the material immediately before its use; also that cyanide should be hermetically sealed at the time of its manufacture.

TABLE V.—*Series "E"—Effects of cyanide gas (HCN) on bedbugs (natural conditions).*

No. of experiment.	Apartment fumigated.	Strength of gas.	Duration of exposure.	Results.	Remarks.
1	Forecastle of ship	0.4 ounce potassium cyanide (KCN) per 1,000 cubic feet of air space.	1 hour	Many dead insects were found; no live insects observed.	On account of ship sailing, no secondary inspection was available.
2	do	1.7 ounces potassium cyanide (KCN) per 1,000 cubic feet of air space.	do	Many dead insects were found; some were observed alive and unaffected.	This fumigation was apparently ineffective.
3	do	2.5 ounces potassium cyanide (KCN) per 1,000 cubic feet of air space.	30 minutes	Many dead bugs were found; no live bugs observed.	Sailors later reported finding live insects. These presumably were ones that had revived.
4	do	5 ounces potassium cyanide (KCN) per 1,000 cubic feet of air space.	1 hour	do	Ten days subsequently ship's officers and sailors stated that no bedbugs had been noticed, though the insects "had been troublesome before the fumigation."
5	do	3.75 ounces potassium cyanide (KCN) per 1,000 cubic feet of air space.	do	Many bugs apparently killed.	Twelve days later the mate of the vessel reported that no bedbugs had been noticed for several days after the fumigation. A week later a few live insects were noted.
6	First mate's cabin in a ship.	5 ounces potassium cyanide (KCN) per 1,000 cubic feet of air space.	do	Many dead bugs were found; no live insects observed.	The mate reported 12 days after fumigation that he had seen one live insect on the eleventh day, but had not been troubled with bedbugs since fumigation; formerly they had been plentiful.
7	Second mate's cabin in a ship.	3.75 ounces potassium cyanide (KCN) per 1,000 cubic feet of air space.	do	All bugs noted were dead	The mate stated 12 days after that whereas "he had been unable to sleep on account of bedbugs before fumigation" he had noticed none since excepting one live insect immediately after fumigation.

In the above procedures bed clothes, mattresses, and other effects were not disturbed before fumigation. From all our observations of the effect of cyanide gas on bedbugs during ship fumigation and from the results of experiments in Series "D," Table IV, we believe that the gas in strength of 5 ounces per 1,000 cubic feet of space (exposure one hour) is sufficient for bedbug destruction under ordinary natural conditions.

TABLE VI—*Series "F"—Effects of sulphur dioxide (SO_2) on bedbugs.*

No. of experiment.	Number of bedbugs.	Container.	Cheesecloth protection to container.	Strength of gas.	Duration of exposure.	Primary inspection.	Final inspection 12 hours later.
				Per cent.			
[1] 1	7	Glass jar, capacity of 6 ounces.	1 layer	1	2 hours	All insects alive	All insects alive.
2	5	do	do	2	do	All insects dead	All insects dead.
3	5	do	2 layers	2	do	do	Do.

4	5	....do	3 layers	2	....do	....do	Do.
5	5	....do	4 layers	2	....do	....do	Do.
6	5	....do	5 layers	2	....do	....do	Do.
7	5	....do	6 layers	2	....do	....do	Do.
8	12	....do	Container packed with gauze and covered by one layer	2	....do	....do	Do.
9	7	....do	1 layer	1	....do	....do	Do.
10	6	....do	6 layers	1	1 hour	....do	Do.
11	6	....do	Container packed with gauze and covered by one layer	1	....do	....do	Do.

[1] REMARKS.—The negative results in experiment No. 1 were probably due to noncombustion of all the sulphur. From experiments Nos. 9, 10, and 11 it seems evident that 1 per cent sulphur dioxide (SO_2) will kill bedbugs at an exposure for 1 hour. On account of possible partial noncombustion of the sulphur the writers believe that a 2 per cent gas should be used; i. e., 2 pounds of sulphur per 1,000 cubic feet of space. An exposure for 1 hour seems effective.

TABLE VII.—*Series "G"—Effects of cyanide gas (HCN) on roaches.*

No. of experiment.	Number of insects.	Container.	Cheesecloth protection to container	Strength of gas.	Duration of exposure.	Primary inspection.	Final inspection.
1	3	Glass jar, capacity of 6 ounces.	1 layer	1½ ounces potassium cyanide per 1,000 cubic feet of air space.	One-half hour	Two insects apparently dead; 1 alive.	All insects alive.
2	20	....do	....do	5 ounces potassium cyanide per 1,000 cubic feet of air space.	1 hour	All insects apparently dead	All insects recovered and alive.
3	4	....do	....do	....do	....do	....do	Three insects dead; 1 alive.
4	9	....do	10 layers	....do	....do	....do	Eight insects dead; 1 alive.
5	(?)	Hold of a ship	None	....do	....do	Many apparently dead roaches observed.	Two roaches retained for observation regained movement after 12 hours.
6	20	Glass jar, capacity of 6 ounces.	1 layer	10 ounces potassium cyanide per 1,000 cubic feet of air space.	....do	All insects apparently dead	All insects dead.

REMARKS.—As roaches possess no known ability to carry quarantinable infection their destruction is desirable only from the esthetic viewpoint. It therefore does not seem justifiable in order to insure cockroach destruction that double the amount of cyanide gas be used as is ordinarily required to kill rats, fleas, or other infection-carrying vermin. For effective cockroach destruction it seems apparent that cyanide in the strength of 10 ounces per 1,000 cubic feet is necessary.

TABLE VIII.—*Series "H"—Effects of sulphur dioxide (SO_2) on roaches.*

No. of experiment.	Number of roaches.	Container.	Cheesecloth protection to container.	Strength of gas.	Duration of exposure.	Primary inspection.	Final inspection.
				Per cent.			
1	10	Glass jar, capacity of 6 ounces.	1 layer	2	2 hours	All insects apparently killed	Nine insects dead; 1 alive.
2	10	do	do	4	6 hours	All insects dead	All insects dead.

REMARKS.—Sulphur dioxide (SO_2) is lethal to roaches in 4 per cent strength, but from practical experience in fumigating vessels, these insects generally reappear shortly after sulphur fumigation. These presumably are those individuals that have secured safe retreat in cracks or recesses during the fumigation or are hatched from the eggs. Cockroach ova are not affected by sulphur fumes. As these insects are not recognized as factors in the transmission of disease their total destruction is not imperative from a standpoint of sanitation.

TABLE IX.—*Series "L"—Effects of cyanide gas (HCN) on body lice.*

No. of experiment.	Number of lice.	Container.	Cheesecloth protection to container.	Strength of gas.	Duration of exposure.	Primary inspection.	Final inspection.
1	5	Iron can, capacity of 16½ gallons.	Container packed with old clothes.	2½ ounces potassium cyanide (KCN) per 1,000 cubic feet of air space.	15 minutes	All insects apparently dead.	All insects recovered.
2	5	Glass jar, capacity of 6 ounces.	1 layer	do	30 minutes	do	4 insects dead, 1 insect alive
3	6	do	do	3.75 ounces NaCN (5KCN) per 1,000 cubic feet.	1 hour	do	All insects revived.
4	6	do	6 layers	do	do	do	Do.
5	6	do	1 layer; container packed with gauze.	do	do	do	Do.
6	6	do	do	do	do	All insects stupefied	Do.
7	6	do	6 layers	do	do	do	Do.
8	6	do	1 layer	do	do	do	Do.
9	6	do	1 layer; container packed with gauze.	5 ounces potassium cyanide (KCN) per 1,000 cubic feet.	do	do	Do.
10	6	do	1 layer	do	do	do	Do.
11	6	do	6 layers	do	do	do	Do.
12	6	do	1 layer	do	1 hour and 15 minutes	do	All insects dead.
13	6	do	do	7.5 ounces sodium cyanide (NaCN) (10 ounces KCN) per 1,000 cubic feet.	1 hour	do	Do.
14	6	do	6 layers	do	do	do	4 insects dead, 2 alive.
15	6	do	1 layer; container packed with gauze.	do	do	do	1 insect alive, 5 dead.
16	6	do	1 layer	do	do	do	4 insects dead, 2 alive.
17	6	do	6 layers	do	do	do	Do.
18	6	do	1 layer; container packed with gauze.	do	do	do	2 insects dead, 4 alive.

19, [1]20	6	....do	1 layer	10 ounces potassium cyanide (KCN) per 1,000 cubic feet of air space.	....do	....do	5 insects dead, 1 alive. 4 insects dead, 2 alive.
21, [1]22	6	....do	6 layers	....do	....do	....do	Do.
23, [1]24	6	....do	Container packed with gauze, covered with 1 layer.	....do	....do	....do	3 insects dead, 3 alive. 4 insects dead, 2 alive.
25	(2)	Galvanized iron can.	Lice-infected shirt rolled up and placed in container.	....do	....do	....do	Many insects recovered.
26, [1]27	6	Glass jar, capacity of 6 ounces.	1 layer	....do	2 hours	....do	All insects dead.
28, [1]29	6	....do	6 layers	....do	....do	....do	Do.
30, [1]31	6	....do	Container packed with cheesecloth covered by one layer.	....do	....do	....do	Do.

[1] Container was placed near ceiling of room. [2] Very many.

REMARKS.—Body lice are more resistant to cyanide gas than the other insects experimented with. It seems evident, however, that the gas in strength of 10 ounces potassium cyanide per 1,000 cubic feet with an exposure for 2 hours is sufficient for the destruction of body lice under ordinary natural conditions. From the results of experiments 26 to 31 apparently there was no difference in the effects of the gas in the upper and lower level of the fumigating room on the insects exposed.

TABLE X.—*Series "M"—Effects of sulphur dioxide (SO_2) on body lice (artificial conditions).*

No. of experiment.	Number of lice.	Container.	Cheesecloth protection to container.	Strength of gas.	Duration of exposure.	Primary inspection.	Final inspection.
				Per cent.			
1	6	Glass jar, capacity of 6 ounces.	1 layer	2	2 hours	All insects stupefied	All insects recovered.
2	6	....do	6 layers	2	....do	....do	Do.
3	6	....do	Container packed with cheesecloth and covered by 1 layer.	2	....do	....do	Do.
4	6	....do	....do	4	6 hours	....do	All insects dead.
5	6	....do	1 layer	4	....do	....do	Do.
6	6	....do	6 layers	4	....do	....do	Do.
[1]7							
[2]8							
[3]9							

[1] Repetition of No. 4, excepting container was placed near ceiling of room.
[2] Repetition of No. 5, excepting container was placed near ceiling of room.
[3] Repetition of No. 6, excepting container was placed near ceiling of room.

REMARKS.—Body lice are apparently more resistant to the fumes of sulphur than are other insects. Sulphur dioxide, 4 per cent strength, with exposure for six hours, is effective for body-louse destruction.